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ABSTRACT

This study was designed to assess the effect of a process oriented elementary science curriculum upon students' achievement. The Iowa Tests of Basic Skills (ITBS) Complete Battery with the social studies and science supplements was administered to sixth grade students completing one, two, or three years of the Science through Discovery program in the Richardson Independent School District, (Texas). The Comprehensive Test of Basic Skills (CTBS) which was administered to these students in the third grade was used as a covariate to control statistically for any pretreatment differences in achievement. The paper concluded that students exposed to process science for three years who only covered 42 percent of the test items performed as well as students who were exposed to 86 percent of the content assessed. Post hoc analyses were conducted using t-tests to examine the issue of gender equity or disparity as a function of the curriculum being implemented and/or test congruence. (Author/YP)

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PROCESS SCIENCE AND STANDARDIZED TESTING: ARE THEY COMPATIBLE?

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PROCESS SCIENCE AND STANDARDIZED TESTING: ARE THEY COMPATIBLE?

Abstract

This study was designed to assess the effect of a process-oriented elementary science curriculum upon students' achievement. The Iowa Tests of Basic Skills (ITBS) Complete Battery with the social studies and science supplements was administered to sixth grade students completing one, two, or three years of the Science Through Discovery program in the Richardson Independent School District (TX). The Comprehensive Test of Basic Skills (CTBS), which was administered to these students in third grade, was used as a covariate to control statistically for any pretreatment differences in achievement. In addition to the ANCOVA's, additional analyses were performed on the students administered the ITBS. Post hoc analyses were conducted using t-tests to examine the issue of gender equity or disparity as a function of the curriculum being implemented and/or test congruence.

Introduction

Historically, science educators have been most critical of the use of standardized tests to assess mastery of science content. The fact of the matter is, however, that within the last decade there has been an increase in the use and frequency of standardized tests. Administrators and school board members view standardized testing as an essential and integral aspect of the process of schooling. A traditional orientation to instruction and testing, however, contrasts with the reconceptualist goals espoused by science educators since the early 1980s.

As we approach the 1990s, science educators must respond to the following dilemma: How can the current goals for science education be addressed within the context of a traditional schooling environment? With the preceding question in mind, we

raised the following pragmatic questions: Are process science and standardized testing compatible? In reality, we were looking to see if the data derived from standardized achievement tests, in the context of a program evaluation, could lend support for the continuance of curricular innovations in science education.

Background

In 1983, the Richardson Independent School District began a five-year plan to implement the Science Through Discovery elementary science program. Students' and teachers' attitudes toward science were assessed during each of the first three years of the implementation.

Students' attitudes toward science were enhanced after being exposed to the program for one year (Kyle, Bonnstetter, McCloskey, & Fults, 1985; Kyle, Bonnstetter, & Gadsden, 1988); and, students' enhanced attitudes were maintained throughout the three-year investigation (Kyle & Bonnstetter, 1987; Kyle, Bonnstetter, Gadsden, & Shymansky, 1988). Teachers' attitudes toward science were equitable, and not overly positive, among the three implementation groups (Kyle, Bonnstetter, & Gadsden, 1988).

Thus, it is apparent that the nature of the science curriculum, in conjunction with the administrative support and the extensive staff development necessary for implementing curricular innovations, contributes to a teacher's ability to implement an innovative curriculum effectively and concomitantly enhance students' attitudes toward science. That is, teachers' *a priori*

negative attitudes toward science neither appear to inhibit the success of an innovative curricular implementation, nor restrict the enhancement and maintenance of students' attitudes.

The Science Curriculum Improvement Study (SCIIS) (Thier et al., 1978) was adopted as the focal component of the overall curriculum. SCIIS was introduced into the district's 35 elementary schools over a three year period of time. During the second and third year of each school's implementation plan, subsequent innovations were introduced in accordance with the Concerns-Based Adoption Model. This component of the project evaluation was designed to assess the effect of one, two, or three years of a process-science curriculum upon student achievement on a standardized test.

PURPOSE

Two questions provide a focus for this study:

1. Are there any differences in the performance of sixth grade students on a standardized battery of tests on the basis of the number of years of exposure to a process-oriented science curriculum?

2. Are there any differences between the performance of sixth grade males and females on a standardized battery of tests on the basis of the number of years of exposure to a process-oriented science curriculum?

PROCEDURES

The Iowa Tests of Basic Skills (ITBS, Form G) served as the primary instrument for assessing student achievement in the Science Through Discovery program. The ITBS was administered in April 1986

to 2,363 sixth grade students in the 35 elementary schools that comprise the Richardson Independent School District. Of the 35 schools, five schools had been implementing the Science Through Discovery program for three years, nine schools for two years, and 21 schools for one year. Thus, while some students had been exposed to the new program for three years (one-half of their elementary school experience), the majority of the students were experiencing process-science for the first time as sixth graders and had been exposed to five years of the traditional science program.

Since the research design included the use of intact groups rather than a random assignment, a covariate was sought to control statistically for any pretreatment differences that might have existed in students' achievement. In addition, a covariate provides for a cleaner, more powerful analysis. The achievement battery administered to these students in the third grade was the Comprehensive Test of Basic Skills (CTBS). Since there were no science sub-test scores for this level, we used the total test and mathematics sub-test scores as covariates in separate analyses.

The CTBS-ITBS merge file resulted in 1,491 cases, representing students who took both the CTBS and ITBS and who participated for the full three years in the district's scheduled implementation plan. Cases not included in the merged file were either: not administered both tests, transferred within the district to a school in a different phase of the project, transferred out of the district, or transferred into the district.

An *a priori* alpha level of 0.01 was selected for this investigation. This determination was rationalized as follows: a) in light of the results of the attitude and classroom observation components of the program evaluation, it was determined that the acquisition of compelling achievement disparity favoring the control group would be necessary to consider substantial revisions to the nature of the curriculum; and, b) the exceptionally large sample size could contribute to the rejecting of the null hypothesis when indeed there are no real effects observed (Type I error). In addition to the merged files ANCOVA's, analyses were performed on the total group of students administered the ITBS. Post hoc analyses were also conducted using two-way ANOVA's to examine possible reasons for gender disparity on student achievement measures in light of the fact that previous investigations revealed equitable attitudes after one, two, and three years of the curriculum implementation.

RESULTS AND DISCUSSION

The analyses of covariance (ANCOVA's) performed on the merged data set showed no significant differences in science scores on the ITBS due to the number of years exposure to the process-oriented Science Through Discovery program after controlling for initial differences on the CTBS Total Score (Table I) and the CTBS mathematics sub-scale (Table II). The ANCOVA's indicated that when students are exposed to a process-science curriculum for an extended period of time that they should not be expected to perform

less well on standardized measures when compared to students exposed to traditional science classes. These findings corroborate the meta-analysis reported by Shymansky, Kyle, and Alport (1983), in which students in new science curricula performed as well or better than students in traditional science courses on measures of general achievement, analytic skills, process skills, and related skills, as well as on affective measures.

The ANCOVA results reported herein contrast with Walker and Schaffarzick's (1974) claim that student performance correlates with the nature of the curriculum being implemented. That is, Walker and Schaffarzick maintained that students in process-science classes should be expected to perform less well on standardized tests when compared to students in traditional science classes. They similarly noted that students in process-science curricula should perform better on measures favorably biased toward the goals of the program. In essence, their contention was that students perform best on measures biased toward the particular course of instruction. Kyle (1982) refuted this contention previously, noting that students in new science curricula performed as well or better than their traditional counterparts regardless of the congruence of the measure (test bias).

These results should alleviate administrators and school board members consternation that teaching process-oriented science will, in and of itself, negatively impact students performance on standardized tests. The ANCOVA results are even more impressive in light of the fact that there was only a 42% item correlation

between the Science Through Discovery program and the ITBS science test vs. an 84% item correlation with the control group curriculum that preceded the Science Through Discovery implementation. Thus, Science Through Discovery students who received the new program for three years performed as well as their traditional counterparts (students who received the traditional program for five years and were in the first year of the implementation) even though they received less than half of the "coverage" for the items on the standardized test. With this remarkable accomplishment, it is worth noting that the overall mean grade equivalent for exiting sixth graders was 8.92 (group grade equivalent range, 8.69 - 9.05).

In accordance with national standardized testing norms and previously reported investigations of gender and science achievement (e.g., Becker, 1989; Steinkamp & Maehr, 1983, 1984), males performed statistically significantly better than females on the ITBS science test in each of the implementation years. The ITBS science achievement x gender x implementation group two-way ANOVA results are reported in Table III.

The prospect that the gender disparity often reported in the literature had been perpetuated throughout the three years of the Science Through Discovery implementation was most disturbing. This was especially true since the attitudinal component of the program evaluation revealed that differences between males and females were ameliorated after one year of process-science and that females' attitudes toward science were maintained at the enhanced level throughout the implementation period. In addition, the

classroom observation component of the overall program evaluation showed that females were engaged with manipulatives (e.g., processing behaviors) for a significantly greater percentage of total class time than were males (Kyle, Bonnstetter, Gadsden, & Shymansky, 1988). Thus, a series of post hoc analyses were conducted to examine science test score inequalities due to gender.

The first series of post hoc analyses investigated whether a particular discipline or "kind" of item contributed to the gender disparity observed. Test items were dichotomized as life science or physical science. We also investigated whether differences existed for items assessing concepts for which students traditionally possess misconceptions. Two-way ANOVA's revealed significant differences with males scoring higher on science achievement for the life science items ($F = 10.169$, $p < 0.001$) and the physical science items ($F = 57.75$, $p < 0.0005$). There were no significant differences observed at the *a priori* alpha level for the misconception items ($p = 0.022$). The analyses revealed that there were no significant differences for the implementation group main effect. Similarly, the analyses indicated that there were no interaction effects.

We then investigated whether there were science achievement gender differences based upon the notion of content coverage of test items. Test items were grouped as follows: items only covered by the Science Through Discovery program (in general, these were higher cognitive domain items); items covered by both the Science Through Discovery program and the previous traditional program (in

general, these were non-laboratory-based factual recall items); items only covered by the control group curriculum previously used in the district (which would likely favor sixth grade students in their first year of the implementation process); and, items not covered by either program.

The two-way ANOVA's showed that there were no significant differences at the *a priori* alpha level for items covered only by the Science Through Discovery program ($p = 0.16$) or for the items covered by both programs ($p = 0.032$). The both programs coverage analysis revealed significant main effects by implementation group. Neither analysis showed interaction effects.

The remaining analyses revealed significant gender differences favoring males, as follows: control group coverage only, $F = 45.118$, $p < 0.0005$; and, items not covered by either program, $F = 7.383$, $p < 0.007$. These analyses revealed that there were no significant differences for the implementation group main effect. Similarly, the analyses indicated that there were no interaction effects.

Thus, the post hoc analyses for content coverage reveal that:

1. Females exposed to a process-science curriculum perform as well as males on higher cognitive domain science achievement test items that are congruent with the nature of the curriculum.
2. Females exposed to a process-science curriculum perform as well as males on low level cognitive domain science achievement test items that are not congruent with the

nature of the curriculum. This analysis reveals, however, that females do not fare as well on items that do not correlate with the nature of the curriculum being implemented.

3. Males perform significantly better than females on science achievement items that are only covered by traditional science textbook-based programs.
4. Males perform significantly better than females on science achievement items that are not part of the school-based curriculum.

These findings appear to indicate that exposure to school-based process-oriented science enhances the performance of females on standardized science achievement test items that are most congruent with the nature of instruction. The gender disparity often reported in the literature may in fact be due to males ability to respond better to low level cognitive domain science items, as well as to items that are not part of the curriculum.

One could speculate that males ability to perform better on such items is a sociological factor related to out-of-school science related experiences that are not traditionally afforded to females. The assessment of females' performance in science, then, should better correlate with not only the content taught, but with the nature of the curriculum as well. It may well be that a more valid assessment of females' achievement in school-based science would be derived from locally developed criterion-referenced evaluation systems (this, of course, would be true for the

assessment of males as well). Female students must not be penalized in the interpretation of science achievement data due to potentially enhanced entering behaviors and characteristics that males bring with them to science classes!

Conclusion

Process-science and standardized testing: are they compatible? The results indicate that students exposed to process-science for three years who only "covered" 42% of the test items performed as well as students who were exposed to 84% of the content assessed. Process science, in and of itself, does not contribute to students performing less well on standardized measures of science achievement. Thus, students, in general, are able to perform as well on standardized measures regardless of the lack of test congruency with the nature of the curriculum. The results of this investigation, in conjunction with the attitudinal and classroom observations associated with the curriculum implementation, indicate that the Science Through Discovery is most successful.

In conclusion, it appears as though it may be more important for there to be test congruency with the nature of the curriculum when assessing the performance of females on measures of science achievement. This notion must be investigated further. The idea that school-based process-science contributes more to the "scientific literacy" of females than males is also a potentially interesting area for further inquiry.

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Table I

Analysis of Covariance of ITBS Science Scores
by Treatment with CTBS Total Score

Source	DF	MS	F
Covariates	1	266871.36	804.11*
CTBS Total	1	266871.36	804.11*
Main Effects	2	946.76	2.85
Treatment	2	946.76	2.85
Explained	3	89588.30	269.94
Residual	1446	331.88	
Total	1449	516.68	

*Significant at the *a priori* alpha level, 0.01.

Table II

Analysis of Covariance of ITBS Science Scores
by Treatment with CTBS Mathematics Sub-scale

Source	DF	MS	F
Covariates	1	196122.50	514.27*
Math score	1	196122.50	514.27*
Main Effects	2	896.93	2.35
Treatment	2	896.93	2.35
Explained	3	65972.12	172.99
Residual	1447	381.35	
Total	1450	517.05	

*Significant at the *a priori* alpha level, 0.01.

Table III

Two-way Analysis of Variance of ITBS Science Scores by Treatment by Gender

Source	DF	MS	F
Main Effects	3	3153.81	6.15*
Treatment	2	1721.21	3.36*
Gender	1	6047.73	11.79*
Two-way Interaction	2	552.60	1.08
Treatment x gender	2	552.60	1.08
Explained	5	2113.33	
Residual	1453	512.79	
Total	1458	518.28	

*Significant at the *a priori* alpha level, 0.01.